# WATER CONFLICT BETWEEN AGRICULTURE AND URBAN AREAS

Rojano Aguilar Abraham[1], Salazar Moreno Raquel[2]
*Universidad Autonoma Chapingo*
*Chapingo, Mexico.*

## ABSTRACT

Reality always generates scenarios as fantastic challenges. For instance some years ago, water had been given as granted and nobody paid attention to it, however, with increasing population this resource has become of great importance and sometimes its deficit causes panic. Not only it is important and fundamental, but also water signifies life for animals and plants in our Earth. Thus, the authors strongly believe that water use and distribution studies have to be done. A simple analysis in the water cycle for any place in the world, the rainfall is somehow constant. Agriculture area does not increase and irrigation techniques can be improved. As a result, some of this water is feasible to save. In counter side, urban water demand is growing up with two main suppliers: surface water coming from lakes, rivers, or channels and groundwater coming from aquifers. Here it is the conflict problem. Agriculture and urban water demands depend on the same sources: surface water and groundwater. Strictly, there is dependency between the sources, however, for primary approximations, they can be considered independent. Mathematically, the demand is a simple function of the supplier or vice versa whenever it is monotonic. Even we believe that function exists, there is no way to make it explicit. Therefore, the problem consists in finding the characteristics of this function.

KEYWORDS: model, aquifer, surface water, groundwater.

*Email:* [1] *abrojano@hotmail.com;* [2] *raquels@taurus1.chapingo.mx*

## Introduction

Fresh water is one of the security resources in the entire world. Fresh water has been recognized as fundamental in the whole history of humankind, and today is one of the factors that could limit the growth of plants, animals, cities and industries. Furthermore, fresh water can be a strong constraint in the modern society. As we believe, only a economical desalinization process can be one of the plausible alternatives.

From reality, it is known that water distribution is a function of space and time $w = w(x,t)$. Any point of the Earth has potentially different rainfall, and different realizations along time. Since the inherent complexity involved in dealing water problems various models have been proposed in order to get across knowledge regarding water distribution. First, the space and time are decoupled to obtain a secuence of stationary problems or time series linked to specific locations. Second, water problems are simulated with real or virtual information to predict future scenarios. Third, water problems are simplified in few variables to recognize some patterns, and feasible conclusions. On the basis of the last alternative, this paper describes a water problem as attained relation between demand and supply. The demand is identified by users like farmers in agriculture and people from the urban areas; meanwhile, the supply is given by surface water and groundwater.

Currently, farmers in agriculture spend water (8000 $m^3$/ha/year) in the open field, approximately; and the urban population uses 0.3 $m^3$/day (109.5 $m^3$/year) per capita (World wide calculations are made

with 400 m$^3$/year per capita.) In fact, there is a decreasing trend in farmers and but not urban areas. Farmers are applying new alternatives like sprinker and drip irrigation, better irrigation schedule and volume control. These techniques are emerging not only for saving water but also for increasing yield and quality products. Even more, water is not ready in the crop field; it is required to conduct it from a river, a lake or a dam, with water losses by either evaporation or infiltration. Citizens in urban areas have not been dealing, appropriately, with the control of local spills in the main water distribution system as well as reducing the water losses inside the houses.

Since demand has been briefly described, water resources are also mentioned, as follows. Despite groundwater somehow came, sequentially, from rain and an infiltration process, for simplicity, it can be considered that the water supply comes from either the rainfall or the aquifers.  Thus, even when rainfall has variability, the average mean is around 500 mm/year. This number gives a potential storage of 5000 m$^3$/ha/year, by completely efficient catching procedures. In reality, it is needed to consider evaporation, infiltration and drainage, and the storativity reduces dramatically. Instead, aquifers are the natural water bank and the pumping is the common way to directly obtain water in the application point (artesian wells are not really many). The advantages of groundwater are the quality, location and ready to be extracted. The disadvantages are getting bigger when drawndown is increasing.
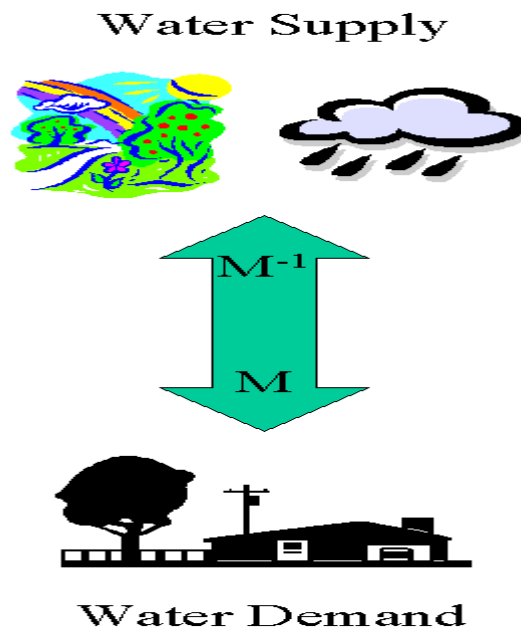


Figure 1. This graphic depicts water interaction between consumption and supply.

**Background**

On the basis of simple theory, we are going to identify the variables involved: total water ($w_t$), surface water ($w_s$), and groundwater ($w_g$), water for urban areas ($w_u$), and water for agriculture ($w_a$). By taking the total water as the point of reference, thus

$$w_t = w_u + w_a = w_s + w_g$$

even the total water used ($w_t$) is increasing with time, and the relationships among its components are nonlinear and complex. Real problems always bring about continuous challenges in many details; however, we can propose for this case a linear and single transformation M (by assumption). For instance, in terms of linear combination of $w_s$ and $w_g$, the $w_u$ and $w_a$ as

$$\begin{pmatrix} w_u \\ w_a \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} \begin{pmatrix} w_s \\ w_g \end{pmatrix}$$

The system above shows the structural form of the concept afforded. The transformation is static and might be valid for short time periods. More realistic conditions like $w_u$ and $w_a$ depending on time lead into a dynamical system. These are the scenarious based on ordinary differential equation systems and so on, and they are not treated here.

Basically, the problem starts when we need to build the coefficient matrix $M = m_{ij}$. We have to find explicit components $m_{ij}$. These stage can be make it from data field, and only from our understanding, we are available to describe the next four simple scenarios as follows

First, $m_{11} = m_{22} = 0$, thus urban area depends on groundwater and agriculture depends on surface water, respectively. This case corresponds to places where there are rivers, lakes or dams, but they are contaminated.

Second, $m_{12} = m_{21} = 0$, thus urban area depends on surface water and agriculture depends on groundwater. This case is not really common, because agriculture uses a lot of water, but cheaper.

Third, $m_{11} = m_{21} = 0$, urban area and agriculture depend on groundwater. This is a common case by areas located in arid lands.

Fourth, $m_{12} = m_{22} = 0$, urban area and agriculture area depend on surface water. This case corresponds to locations near to permanent rivers and the problem is drainage.

**Analysis of Transformation M**

Let see how the matrix M behaves in terms of characteristic values. The eigenvalues of M in general correspond to second-degree polynomial equation

$$\lambda^2 - (m_{11} + m_{22})\lambda + m_{11}m_{22} - m_{12}m_{21} = 0$$

The roots of this polynomial give us the critical points in which it is possible to find corresponding identification with the four analyzed cases mentioned above. This is straightforward obtained as

$$\lambda_1 = \frac{m_{11} + m_{22}}{2} + \frac{\left((m_{11} - m_{22})^2 + 4m_{12}m_{21}\right)^{0.5}}{2}$$

$$\lambda_2 = \frac{m_{11} + m_{22}}{2} - \frac{\left((m_{11} - m_{22})^2 + 4m_{12}m_{21}\right)^{0.5}}{2}$$

Let us follows the analysis of M by using the eigenvalues

Case 1:  $m_{11} = m_{22} = 0$. The equation corresponds to

$$\lambda_1 = \left( m_{12}\, m_{21} \right)^{0.5}$$

$$\lambda_2 = - \left( m_{12}\, m_{21} \right)^{0.5}$$

Case 2. $m_{12} = m_{21} = 0$,

$$\lambda_1 = m_{11}$$

$$\lambda_2 = m_{22}$$

Case 3. $m_{11} = m_{21} = 0$,

$$\lambda_1 = 0$$

$$\lambda_2 = m_{22}$$

Case 4. $m_{12} = m_{22} = 0$,

$$\lambda_1 = m_{11}$$

$$\lambda_2 = 0$$

Mathematically, the transformation M belongs to the fourth-dimensional space, and we cannot plot the transformation, because its graphic requires five dimensions. When the eigenvalues are obtained; the dimension reduces automatically. However, the dimensions can be less when we use the determinant function and we assume some example of plausible synthetic relationships between components alike

$$Det(M) = \det \begin{pmatrix} x & 1-y \\ 1-x & y \end{pmatrix}$$

In terms of linear weights, this function (Figure 3) can be seen in 3 dimensions.  This figure 3 shows us the projected limits on three dimensions where many reality problems can be located (see the straight line where determinant of M vanishes.)
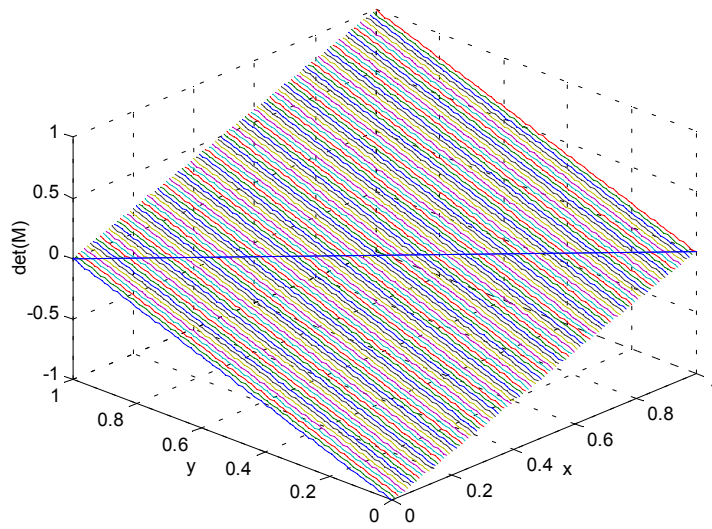
Figure 3. This graphic describes the determinant function of the matrix M.

**Application example**

A typical place like Mexico City has the following data, thus finding the matrix M is a procedure with many solutions. However, some of those solutions where determinant vanishes is part of this presentation

$$\begin{pmatrix} w_u \\ w_a \end{pmatrix} = \begin{pmatrix} 0.8 \\ 0.2 \end{pmatrix}$$

$$\begin{pmatrix} w_s \\ w_g \end{pmatrix} = \begin{pmatrix} 0.1 \\ 0.9 \end{pmatrix}$$

By solving the resulting equations, the obtained transformation M is

$$M = \begin{pmatrix} 0.8 & 0.8 \\ 0.2 & 0.2 \end{pmatrix}$$

This matrix is singular and it has no inverse, but eigenvalues

$$\lambda_1 = 0$$

$$\lambda_2 = 1$$

By using the clasification established before, it seems to be that this example corresponds directly to the Case 3, however this example match up with the general case when agriculture and urban population depend on surface water and groundwater simultaneously.

**Discussion**

Water is a natural resource that we cannot create, it only moves in the atmosphere, over the ground and underground; it is a resource for applying only an efficient management, still when the water is desalinate. Chemical generation of water is far beyond on the purposes of this paper. Furthermore, it is required to understand the water cycle for high-quality decisions. Somehow urban and agricultural users as well as surface water and groundwater are strongly linked in water cycle. Thus, it is needed to record the water flow in the water cycle. This requires understanding rainfall, runoff, evaporation, transpiration, and infiltration as well. These components have to be gotten across in order to obtain the real scenario for applying the transformation matrix M as pointed out above.

Science is useful to understand and describe the phenomenon. The problem addressed is linked to global, regional, and local scales. The physics of water cycle is both described and explained in terms of mass conservation, momentum conservation and constitutive relationships. However, bounding the domains appropriately is always a limitation of the current models. Water evaporation in America would precipitate in either Europe or Africa. Regional balance can be attained in defined basins or transferred from one to the other, and finally single farmers can afford local studies. By normalizing the amounts of water in both sides of the transformation, the matrix M is useful for spanning all cases of combinations of the domain elements.

Technology is applied in both sides of the transformation M. Water consumers in the city are rising its volume even using better toilets, better connections with less leaking, and governments are cutting the local leaking and non-point water losses in the delivery system. Water volume in agriculture is decreasing because the more efficient application yields into more mass volume and better crop quality. In the other side (supply), surface water requires an integral management with appropriate reforest, dams construction, rain harvesting, efficient conduction, and volumetric measurement. Groundwater is the water bank where withdraws have to be rationalize.

Regardless of limitations and unlikely models, the mathematics not only could play with yielding physical principles involved in how either the water moves or infiltrate, but also provides the transformations M for linking consumers and supply as a game. This paper contributes in proposing and finding a function away from standard procedures.

**Conclusion**

It is assumed that we can predict the best behavior for a particular variable, independent of what others behave. Thus, the crucial aspect of this problem is finding the best alternative among different options. The game consists in detecting the players (water users and water suppliers), and the outcome of their strategies is recorded in the matrix M. By observing the normalized problem, both columns of the matrix M are the vectors of water users. This matrix works for any normalized vector of the water supply, and matematically, the columns of matrix M correspond to suppliers and the rows to

consumers. The fundamental problem *is to find de equilibrium*. That is the right solution, whatever the result in terms of suppliers; the water problems will increase when the availability of surface water decreases but even more when groundwater resource goes down beyond economical limitations.

**References**

[1] The Joint Academics Committee on the Mexico City Supply, *Mexico City's Water Supply*, National Academic Press, Washington D. C., 1995.

[2] Wood W.W., *A Fresh Water Odyssey: Some Observations on the Water Resource*, Groundwater, vol. (41), No. 3, May-June 2003.

[3]  Strang G. *Introduction to Linear Algebra*, Wellesley-Cambridge Press, USA, 1993

[4]  Fudenberg D., Tirole  J.  *Game Theory*,  MIT Press, 200